**Memo to:** Patrick Morris, Senior Water Control Engineer Mercury TMDL Unit, Regional Water Quality Control Board, Central Valley Region
**From:** Professor Alex Horne (UC Berkeley), Reviewer
**Re**: Addendums to the Sacramento-San Joaquin Methymercury TMDL Draft Report
**Date**: 1 September 2006


**SUMMARY**
The Regional Board's staff and their contract research workers have done much good work on methylmercury (MeHg) in the Delta and the addendums and TMDL documents themselves contain much valuable information based on sound science. However, given the unusual chemistry of mercury and the special wetland ecology of the Delta it is likely that the proposed solutions will cause more harm than good. There are five scientific concerns: loss of Delta habitat, arbitrary decisions, unclear mass balances, unethical scientific practices, and fossilized standards. The main instructions given to reviewers are not appropriate. They request the reviewer to give detailed amendments to specific sections assumes that the reviewer accepts the initial findings from which all the details are spawned. Unfortunately, in the special case of MeHg, this assumption is not met. However, the instructions to the reviewer do contain a request for any "over-arching concerns". These are included below and are most important in the way the proposed MeHg standards will restrict the restoration of the Delta and its wildlife. The solution to the impasse may not be soluble under existing rules and will require the Board to define a new paradigm for pollution trading. Thus my only option is to find that the "No Action" alternative is the only way to save the biota of the Delta. A provision to reduce total mercury from the Cache Creek area and in mountain stream is an imperative that should not be affected by this no action alternative.


**1. Loss of Delta habitat.** The overriding ecological need in the Delta is to restore as much habitat as possible to its original tidal wetland state. A minimum of 300,000 acres of restored wetland are needed since about 850,000 were lost. All other concerns are relatively minor. Although the restoration of the Delta is not the Board's main responsibility, in its MeHg TMDL addendums proposal the single-minded pursuit of mercury control threatens Delta restoration. In effect the TMDL will throw the baby (the Delta) out with the bathwater (excess MeHg). Some Delta wetlands produce MeHg from inorganic Hg entering from the Coast Range and Sierra streams and also from aerial deposition. Since these sources are unlikely to be reduced very much in the next 50 years, large amounts of this Hg will be converted to MeHg at levels in excess of the proposed standards. Thus restoration of wetlands in the Delta is effectively prevented since unattainably large MeHg offsets will be needed. This point is well known to the Board staff (e. g. section 3.5 and key points on p. 26 of the TMDL documents). However, the Board does not guarantee that such offsets will be available in anything like the quantity needed and indeed, indicates that they may not be available.

The obvious scientific solution is to balance the potential harm of MeHg production in wetlands with the certain large ecological benefit of these wetlands. However, the Board lacks the trading machinery to offset high levels of mercury with anything but decreases in the same element elsewhere. Urgently needed is a trade (offset) between wetlands restoration benefits and MeHg production. Currently the

Board only offsets like with like (i. e. Hg with Hg) not mercury with, for example, increase in habitat area. It is not sound science to restrict the certain benefits of restoration of the Delta for possible harm caused by low levels of MeHg. This argument applies with even more force to endangered wildlife where the supposition of harm from MeHg may result in the loss of the habitat which would allow the full recovery of the species.

**2. Arbitrary decisions.** Not enough is understood about the environmental chemistry of mercury in the Delta to make informed scientific decisions (for example what controls MeHg in wetlands). The Board's staff is very aware of the uncertainties about the synthesis of MeHg in the Delta occurs in wetlands. In the documents provided it is thought that sulfur may be involved. In the work of my own group at UC Berkeley we have found that iron and redox are also important (these factors are not considered in the TMDL documents provided suggesting 3b errors and incomplete rather than unsound science). Overall, the thermodynamics of the production of MeHg dictate that very low redox potential (and thus the kind of plants in the wetland) is important. My view is that making detailed plans for allocations of MeHg loading are thus premature until more is known about how to construct large seasonal and permanent wetlands that do not produce very much MeHg. More logical at this time would be an attack on the known main sources that are understood (old mines, sediment from these mines, other external sources) since the chemistry and hydraulics of these large sources is known. The Board's comments that much Hg in river sediments is essentially uncontrollable contrasts with the Board's certainty that other equally difficult sources can be controlled or offset.

**3. Mass balance concerns**. The main strategy of the board for all but the smallest entities is to offset any their MeHg in other Delta areas. This provision becomes important for large uncontrolled wetlands such as the current main in-Delta source, the Yolo Bypass wetlands. As more such large wetlands are restored in the Delta is not clear is there is sufficient offset available. For example, the Board's documents are vague in indicating the offset value of the Cache Creek Settling Basin in comparison with the detail of the amounts of MeHg allowed by each discharger in each site. Are there enough MeHg (or Hg) offsets in the Delta to allow its restoration? If non-similar offsets were allowed as indicated above then this question would go away.

**4. Unethical Scientific Practices**. Although sounding rather grim, unethical scientific practices are common flaws and normally easily corrected. In any large work such as that carried out by the Board's staff or similar reports that I have written, a few unethical scientific practices tend to seep in here and there. All scientists are potentially guilty of such lapses and there are accepted rules to correct them. The prime errors are classified as (i) Positive Operator Bias (POB) which is usually an unconscious selection of non-representative data (usually a extreme high or low) and (ii) 3b errors commonly thought of as errors of omission or "cherry-picking" of available data. Because many of us, including the Board's staff are keen environmentalists, these two errors are hard for the writer to keep out even as they are obvious to the reviewer.

In this report the usual POBs occurred in terms of always choosing the most conservative value rather than a mean or representative values. Good science requires

use of the representative means. A safety factor which is usually not based on science can then be added at the end if conservative values are needed for political reasons. Thought it seems good to use extreme values, the use of low or high estimates at all stages of the calculations can result in "silly" high or low standards. In almost all cases the Central Valley Regional Board's staff has followed this method in the TMDL and water quality addendum documents reviewed here. However, in some cases this method has not been followed. For example the assumption that 100% Hg in fish is MeHg for purposes of monitoring rather than the average of 85-100% (~ 93%?) as was found in the data is one example of POB. The 3b errors are harder to detect but the mitigating effects of Se on MeHg toxicity and the lack of evidence of MeHg toxic effects in currently high MeHg areas are two examples. Se is abundant in the south delta and is well known as a natural or accidental antidote to Hg toxicity (much work has been carried out on European raptors). Other examples are shown in the main text of my comments.

The main unethical problems do not appear to be in the work of the Board's staff but in the work on which they have relied, especially the mercury toxicity studies of the USFWS (the key to the entire Board calculations appears to be a study on mink and mercury carried out by the USFWS to establish a base line for mercury concentrations vs. health effects). I have not reviewed this secondary work here since it was not in the mandate. However, in my reviews of this agency's work in the past I have found that the USFWS does not have a policy to remove POBs and type 3b errors which are thus often rife. In some cases the toxicity studies are set up so that the LC50 or similar measure is lower than would normally occur using sound science. While we all want a measure of safety in our toxicity predictions, the safety factor should be added on a the end not within the experiment. Thus their work (in this small area at least is not sound science, though the intentions are good; I cannot comment on other responsibilities of the USFWS). It is not my place here to have the Regional Board staff judge the quality of the work of a federal agency but if this work could be validated by a more reliable independent non-agency study I would feel more comfortable about the compromises that would be made if a lower Hg standard was applied in the Delta.

**5. Fossilized standards.** The report is written as if future flexibility can occur in standards. This is not likely and has become a huge flaw in the scientific part of the standard setting mechanism in California and the US as a whole. The proposed MeHg standard in water as suggested in the report is based on the Regional Board staff (and other's) excellent and extensive field work on fish and water and some nice science-based regressions. Nevertheless the addendum recommendations are somewhat arbitrary. The #4 option chosen still does not protect human Delta residents who consume large amounts of some locally-caught fish. The rare bird consumption values are inflated by not considering feeding outside the Delta and may bias the resulting standard. The proposed standard may also be artificially low since it is based on a USFWS toxicity study. Why not chose the less protective options #3 or #4 and then change these as experience and more information become available? There are also numerous smaller decisions in the report that are best justified as "as good as we can do with the existing information." Such compromises are inevitable but experience has taught us that it is virtually impossible to modify standards or Basin Plan Objectives, even if the future scientific evidence is overwhelmingly in favor of changes. The case of

the regulation of copper in San Francisco Bay shows that the poor chemical understanding of copper chemistry by regulators in the 1970s was maintained for over 25 years in the face of a huge mass of more scientific evidence. Millions of dollars were wasted in protecting the wrong thing. Will this happen with MeHg in the Delta? Will the even less well understood chemistry of MeHg remain in statutes for similar periods? The emphasis on the wrong toxicant or form of toxicant has considerable ecological costs since funds wasted could be spent on real toxicity problems or habitat improvements.

**A NEW PARADIGM FOR POLLUTANT TRADING**

As discussed briefly above in item #1, I am concerned that focusing single-mindedly on MeHg, the restoration of the Delta will be constrained or prevented. The situation is unique to heavy metals with an actively metabolized organic fraction and districts with extensive wetlands. Thus my concern so may be confined to mercury, selenium and perhaps arsenic and Central Valley regions. Thus other TMDLs' on which this mercury TMDL is based may not be fully appropriate templates.

In my opinion the only sound scientific way to achieve the Board's objectives is to use some other currency for offsets. For example, the Yolo Bypass and other wetlands to be created to restore the original Delta are a large environmental good. Farms also are a social good. Both wetlands and farms may increase MeHg. To remove these wetlands or farms or require them to pay for mercury cleanup upstream is bad for the Delta. The Board must use science to balance the good of wetlands or farms against the harm of MeHg production. Perhaps, as the report indicates, wetlands and farms can be managed to produce less MeHg. However, a preliminary finding on this topic dated June 2006 obviously was not the driving force of the Board's TMDL written earlier.

I have suggested a new trading paradigm before. In the Santa Ana Region the case of Lake Elsinore is an example. In this case I suggested a swap of N & P for lake water level. This lake in a very dry area sometimes dries up and is often very shallow which degrades water quality and impairs beneficial uses. The Santa Ana Regional Board has been adventurous in allowing the use of reclaimed water containing nutrients to be used to provide makeup water for Lake Elsinore. However, this regional board also required pound for pound N and P offsets for the nutrients added along with the water. I calculated that the benefits of an increased foot of water were about $2.3 million/yr. The costs of providing offsets conventionally can be high (especially at lower N & P levels in wastewater where nutrients have been removed to quite low levels). Thus much of the benefit of the higher water level was consumed by increased water and in-lake treatments. Thus there is a considerable impediment to improving Lake Elsinore because trading in N & P can only be for other N & P offsets. If N & P additions were traded for water elevation increases then a more logical trade would occur. Similarly trading MeHg for other benefits such as increased wildlife habitat area seems to be a vital ingredient in the Delta region.

**DETAILED COMMENTS**

Once a standard of MeHg was decided, the vast bulk of the report is good since most conclusions follow from the initial decision. I will analyze the key item; the five alternatives in the section 3 (Water Quality Objectives) of the Amendments document. Here the driving focus is "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in humans, plant, animal or aquatic life." The criterion used is the CRT criterion of 50 ng/L total recoverable Hg in the water column (this criterion is not exceeded anywhere in the Delta except downstream of the Cache Creek settling basin and a couple of other sites according to the TMDL document, pg 18). These two definitions do not produce the numerical objectives specified later in the document but these numerical objectives are needed by the Board to determine progress in attaining the beneficial uses.

**COMMENT. The option #4 is chosen.** As described elsewhere any option that reduces the likelihood of the re-creation of tidal and other wetlands in the Delta is self defeating. The wildlife may be totally free of possibly toxic MeHg, but that will not matter. There will be no wildlife to save. The reality is that several million of the 20 million more Californians that will be in the state in 2050 will live in and around the Delta. Without a lot of larger new wetlands the wildlife will vanish. Thus the MeHg standard should take note of the changed environment. As also stated elsewhere this problem is more or less unique to the case of mercury and the Delta region and so other Regional Boards may not face such a trade off.
**SUGGESTION**. Go with the No Action alternative at this time with provisions to reduce the Cache Creek and upstream mercury. Intensify research on how to run wetlands to give lower MeHg outputs (consider redox as the master variable here). When that question is solved then many sections of the current reports may be appropriate.

**COMMENT. Anoxia (Redox) in the sediments as a cause of methylation.** I was surprised that the oxygen level or more precisely anoxia, was not considered in the five conditions controlling MgHg production in the TMDL documement (pg. 20). Since the addition of oxygen even at levels of 0.1 mg/L is an experimentally demonstrated method to prevent methylation it is obviously of concern in the Delta. It is also a potentially controllable situation in some areas including wetlands that are so important in in-Delta MeHg production. Oxygenation of water is a simple and inexpensive process and can be increased in wetlands by the choice of plants and hydroperiod.
**SUGGESTION**. Add the role of oxygen and low redox to the appropriate section and consider solutions to methylation in Delta habitats at risk. Low redox is not normally needed for Delta wetlands which will denitrify waste nitrate and grow insect food for birds and fish without methylating mercury.

**COMMENT. Piscivorous fish are assumed to obtain all of their fish or other aquatic prey from the local water body so no relative source contributions (RSC) are used (TMDL document p 29).** Unless I have misunderstood the sense or the report, this is an example of both POB and possible 3b ethical error. The POB is obvious in that most

birds move or migrate over days and seasonally. Thus they may feed on MeHg contaminated food on one day (week) and uncontaminated food on the next. This kind of migration bedevils field toxicity studies but must nonetheless be accounted for. Thus the bias gives a much higher accumulation number than the likely true value. Feeding patterns of most birds are well known but only those for rare birds drive this consideration. For example, the three threatened birds listed in the report (p. 30) include the least tern which is reported to winter south of the USA suggesting that using the correct RSC would considerably lower the amount of lifetime MeHg that they consumed. The two other threatened species mentioned, bald eagles & peregrine falcons also migrate considerable distances and the falcons do not eat much fish. I am aware that the consideration of threatened birds includes the notion that all individuals not just the population be considered. However, this is not a scientific notion and thus is not sound science. In addition the Endangered Species Act suggests that the habitat and its species are more important than preservation of individuals (the "no-zoo" approach).

The possible 3b error is that these feeding studies are very likely to be available elsewhere suggesting cherry picking of the data to support lower Hg standards than scientifically justified.

**SUGGESTION**. Determine and use the correct RSC MeHg input and diet for the rare species involved. Use this to correct the level of MeHg needed in to protect threatened species to a higher level (if appropriate).

**COMMENT. USFWS guidance to the Regional Board on exposure parameters.** This reviewer is not privy to these guidance parameters but past experience with the USFWS in the Central Valley indicates that POB and type 3b errors are common in USFWS reports. Sound science cannot operate in these opaque conditions.

**SUGGESTION**. However, the Board's staff could review USFWS advice, compare it with unbiased information, and ensure that POB and type 3b errors do not unduly change their MeHg standards.

**COMMENT. Dilution of MeHg with increased biomass.** In a recent MeHg project in which I was involved in New York (Lake Onondaga), the restoration of the biota was considered to dilute the available MeHg. The situation is the same in the Delta. The Hg inputs are constant or declining. Thus if more wetlands and more wetlands biota are created the MeHg/individual will decline. In addition, some Hg may be stored permanently in the deeper sediments of the wetlands where it is biologically unavailable.

**SUGGESTION**. Calculate the dilution and use the factor obtained to monitor the biota to determine if the proposed standards can be lessened.

## A PERSONAL COMMENT ON MERCURY TOXICITY

I have had personal and professional experience with the horrors of organic mercury. As a high school boy in England I sometimes had to help my senior chemistry teacher who had experimented with organic mercury in his undergraduate days before the First World War. His shaking hands and permanent pain were a shock to me and a reminder of the damage of chemicals even before Rachael Carson's "Silent Spring." Of course

mercury's dangers were not well known then and his nervous system had been damaged for life. As a teenager I had the harrowing experience of nursing wild birds during the grotesque dance and convulsions they undergo before dying of mercury poisoning from eating seeds on farmland coated with organic-Hg. Finally, as a teacher I taught that the Minamata tragedy in Japan that was due to careless and prolonged releases of large quantities of mercuric acetate to the ocean close to fishing grounds. Jan Ui's book on this topic was particularly revealing (Ui, Industrial Pollution in Japan, 1992, Chapter 4). These were not pleasant experiences and I fully support reduction of mercury and especially organic mercury in the environment.

However, the situation in the Delta is not that of early 20th century scientists, or the 1950s industrial and farmland releases and uses of mercuric acetate. The Delta's case is altogether less serious and the sources more tenuous and less controllable (at present). The Board's report indicates that many cleanups (e. g. new wetlands) will not begin seriously in 2014 and that the overall major source cleanups may take hundreds of years to work. And even then human health is not fully protected. The proposed numerical MeHg solutions look as thought they could prevent the restoration of the Delta wetlands and thus destroy the wildlife resource they seek to protect. Something is wrong.

**NOTE ON ERROR TERMINOLOGY**

**The POB or Positive Operator Bias** is more or less self explanatory. We all make unconscious choices even when trying to be fair. The common example used is to ask students to take toothpicks from a pile but not to select any one size. After the choices is it usually found that they unconsciously select the largest. In scientific work there is often a choice of which number to use. Bias then can slip in. Since the selection is usually to support the hypothesis of the worker the bias is usually positive or in favor the hypothesis. In his case the POB will be to be more protective of wildlife and humans from MeHg toxicity than strictly merited by the science.

**Type 3b errors.** This term comes from a concern about sound science from the US Congress in the 1990s. It will be remembered that some disputed scientific findings made headlines (possible falsification of data on mice in the large genetics laboratory of a Nobel Laureate Dr. Baltimore or a USGS scientist who falsified, or rather invented, studies on cobalt reserves in the US – the US is short of cobalt reserves which are needed for military steel applications. Cobalt its sources world wide are located in unstable or unfriendly nations) and continue to do so today (recent alterations of particle track data by physicists hoping for a Nobel Prize for discovering a new particle). Congress asked the National Science Foundation via its National Science Council of 12 selected experts to provide some ethical guidelines (Commission on Research Integrity). The summary is shown below.

> "It is a fundamental principle that scientists be truthful and fair in the conduct of research and the dissemination of its results. Violation of this principle is research misconduct. Specifically, research misconduct is significant misbehavior the fails to respect the intellectual contributions or property of others, that intentionally impedes the progress of research, or that risks

corrupting the scientific record or compromising the integrity of scientific practices.

Examples … include but are not limited to:

1. **Misappropriation**: An investigator or reviewer shall not intentionally or recklessly (a) plagiarize, which shall be understood to mean the presentation of the words or ideas of another as his or her own, without attribution… or (b) make use of any information in breach of any duty of confidentiality.
2. **Interference**: An investigator or reviewer shall not intentionally and without authorization take or sequester or materially damage any research-related property of another …"
3. **Misrepresentation**: An investigator or reviewer shall not with intent to deceive, or in reckless disregard for the truth (a) state or present a material or significant falsehood; or (b) <u>omit a fact so that what is stated or presented as a whole states or presents a material or significant falsehood</u> …"

The 3b errors of omission problems (data or conclusion cherry picking) are very common in science. The discussion section in most discussion in scientific paper ignores type 3b errors in their quest to justify the conclusions of the paper. The popular trend to mix results and discussions has made these 3b errors even more common since results (facts) can now be mixed willy-nilly with speculations (discussions). Thus it is not surprising to find that 3b errors crop up in reports such as those discussed in this review.